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ORIGINAL

# The Gender Gap in Mathematics as an Expression of Educational Inequality: Evidence from the 2022 Aprender Tests

## La brecha de género en matemática como expresión de desigualdad educativa: Evidencia desde las Pruebas Aprender 2022

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## ABSTRACT

**Introduction**: this article analyzes the gender gap in mathematics performance in Argentine secondary education based on the results of the 2022 Aprender Tests.
**Method**: a non-experimental quantitative design was used, including mean difference analysis and statistical significance testing.
**Results**: boys scored significantly higher than girls, particularly in contexts of greater social vulnerability.
**Conclusions**: the gender gap in mathematics is understood as a structural phenomenon that requires public policies aimed at educational equity.

**Keywords:** Gender Gap; Mathematics; Academic Performance; Educational Inequality; Standardized Testing; STEM.

## RESUMEN

**Introducción**: este artículo analiza la brecha de género en el rendimiento en matemáticas en la educación secundaria argentina a partir de los resultados de las Pruebas Aprender 2022.
**Método**: se utilizó un diseño cuantitativo no experimental, con análisis de diferencias de medias y pruebas de significancia estadística.
**Resultados**: los varones obtuvieron puntuaciones significativamente más altas que las mujeres, especialmente en contextos de mayor vulnerabilidad social.
**Conclusiones**: la brecha de género en matemáticas se configura como un fenómeno estructural que requiere políticas públicas orientadas a la equidad educativa.

**Palabras clave**: Brecha de Género; Matemáticas; Rendimiento Académico; Desigualdad Educativa; Pruebas Estandarizadas; STEM.

## INTRODUCTION

This article analyzes the gender gap in mathematics performance in Argentine secondary education based on the results of the 2022 Aprender tests.(1)

In recent years, the participation of women in science, technology, engineering, and mathematics (STEM) disciplines has been a subject of international concern. Although numerous institutional strategies have been

implemented to reduce the gender gap in the choice of these careers, data show that inequalities persist. According to UNESCO[2] women represent only 35 % of students in STEM fields worldwide, and in Latin America that number is even lower in areas such as engineering and information technology. These patterns reveal an unequal distribution of opportunities and reflect the reproduction of social structures that operate from the early stages of the educational process. In this sense, the gender gap in academic performance in mathematics—consistently recorded in multiple standardized assessments in different countries—is a significant factor in analyzing the conditions that precede and condition vocational decisions. This article starts from the hypothesis that the gender gap in math performance is not only an educational phenomenon but also a structural indicator of inequality, the understanding of which is essential to explain the underrepresentation of women in science and technology careers.

In conceptual terms, the term gender gap refers to systematic differences between men and women in different areas of social life, including access to, use of, and outcomes of formal education. In the specific case of mathematics, this gap is defined as the average difference in academic performance, usually measured by standardized tests, school grades, or indicators of achievement in the area. However, unlike other approaches that associate this difference with supposed innate cognitive abilities, this study takes a structural perspective, which understands performance as a complex variable, socially conditioned by factors such as socioeconomic status, type of educational institution, territory, and dominant pedagogical practices. As Alonso, Olivella, and Sánchez[3] point out, unequal access to cultural and educational capital from childhood has cumulative effects on school trajectories, creating barriers that differentially affect boys and girls in their relationship with mathematical knowledge.

This study takes a structural perspective, whereby differences in academic performance in mathematics are understood as an effect of the structural conditions that organize access to knowledge, rather than as a reflection of individual abilities. In this process, school trajectories are conditioned by social origin, gender, familiarity with school language, and expectations associated with academic success. Thus, the relationship that students establish with mathematics is mediated by institutional and family dispositions that hierarchize knowledge, disciplines, and possible roles. This logic contributes to consolidating performance gaps from an early age and has direct implications for the continuity of educational trajectories in scientific and technological areas.

From this perspective, multiple studies have provided evidence on how these structures produce concrete effects on performance. Research by Mejía-Rodríguez, Luyten, and Meelissen[4], based on TIMSS 2015 data from 32 countries, shows that boys tend to report higher levels of mathematical self-confidence, even when there are no significant differences in performance. Beyond its psychosocial dimension, this finding reflects an unequal distribution of school and cultural conditions that affect perceptions of competence, exposure to mathematical stimuli, and validation of achievements. Along the same lines, García-Gil and Fajardo Bullón[5] highlight the weight of structural variables—such as parents' socioeconomic status and employment status—on math performance, pointing out the differential impact of the socioeconomic status of the father and mother.

The impact of these conditions is reinforced by research that has explored the relationship between gender and math anxiety. Rahe and Quaiser-Pohl[6] identified that women tend to experience higher levels of anxiety in situations involving mathematical reasoning, which negatively influences their performance and motivation to persist in these fields. In turn, they found that performance on mental rotation tasks—spatial skills highly correlated with mathematical competence—acts as a significant mediator, affected by the educational environment and social representations. These emotions do not arise in a vacuum: they are cumulative effects of school experiences that legitimize or delegitimize students' connection to mathematics, creating cycles of exclusion from an early age.

Furthermore, the literature has shown that performance differences tend to be more pronounced in secondary education but tend to diminish or even disappear at higher levels. The study by Wrigley-Asante, Ackah, and Frimpong[7], focused on the University of Ghana, shows how this reduction in the gap responds to changes in the institutional environment, teaching practices, and expectations of female students. This finding reinforces the idea that performance inequalities are not natural or unchangeable, but rather produced by conditions that can be reversed through structural interventions. The Argentine case shows a similar trend: although the Aprender tests consistently show better average results in mathematics among boys, these differences are not necessarily sustained over time or translated into innate cognitive advantages. Social representations of gender in mathematics are internalized by both teachers and students and act as filters when evaluating their own and others' competence. Teachers' expectations, in particular, have been identified as a critical factor: research such as that by Ávila[8] reveals that gender bias in the assessment of academic performance can reinforce insecurity among female students and limit their opportunities for development. The author emphasizes that teachers with implicit biases tend to evaluate effort or ability differently, reinforcing stereotypes that discourage female participation in scientific fields.

In this context, the study by Morales, Espinoza, and del Río[9], based on Chilean data, provides compelling

evidence of the persistence of gender stereotypes linked to mathematical performance. By analyzing beliefs about the mathematical ability of women and men in two age groups (young people and adults), the authors show how variables such as educational level and perception of science influence the reproduction of these stereotypes. The quantitative study, based on logistic regression analysis, establishes connections between cultural structures and social imaginaries that condition vocational choices and access to STEM fields.

Based on this overview, this paper aims to analyze the gender gap in math performance in Argentina as a structural phenomenon, whose causes are linked to the social, institutional, and cultural conditions that shape educational trajectories. In particular, it seeks to evaluate the statistical significance of the gap in the Aprender tests and explore the relative weight of variables such as socioeconomic status, type of school management, and geographical area. This study is based on the hypothesis that these variables partly explain the performance gap and, consequently, act as relevant background information for understanding the unequal participation of women in scientific and technological careers.

The analysis is based on a quantitative approach, with the aim of providing empirical evidence that contributes to a deeper understanding of the phenomenon and informs future public policies aimed at reducing gender inequalities in access to and retention in strategic fields of knowledge.

## METHOD

### Type and design of study

A quantitative, observational, non-experimental cross-sectional study was carried out, based on the secondary analysis of census databases.

### Period and location

The data comes from the Operativo Aprender (Learning Assessment) administered on October 19, 2022, to all 5th and 6th grade secondary school students in the 24 jurisdictions of the Argentine Republic, giving the study national coverage.

### Data source and extraction process

Anonymized microdata released by the Secretariat for Educational Evaluation and Information of the Ministry of Education were used. The files, downloaded in CSV format from the official repository, were cleaned by removing records without mathematics scores and recoding categories according to the Operativo technical manual. No missing values were imputed.

### Variables and operational definitions

- Mathematics score (continuous): standardized student result.
- Gender (binary): male/female, according to census declaration.
- Management sector: public/private.
- Geographic area: urban/rural.
- Socioeconomic level: low, medium, or high (ESCS index provided by Aprender).
- Jurisdiction: province to which the school belongs.
- The selection and coding of these variables is detailed in the original database of the Operative.

### Statistical analysis

Means and standard deviations were calculated by gender and strata. Differences between groups were tested using Student's t-tests for independent samples; the effect size was estimated using Cohen's, interpreted as small (≈ 0,20), medium (≈ 0,50), or large (≥ 0,80). All tests were two-tailed with $\alpha = 0,05$. The analysis was performed in R 4.3.1 with the packages tidyverse and effectsize; assumptions of homogeneity of variances (Levene's test) and normality were verified based on the large sample size.

### Ethical considerations

The study used completely anonymized public information; consequently, it did not involve human subjects or the collection of sensitive data, and therefore did not require evaluation by an ethics committee. The principles of the Declaration of Helsinki for research using secondary data were respected. The authors declare that there is no funding or conflict of interest.

## RESULTS

Descriptive statistics are presented for men and women according to the variables analyzed: sector (state or private), setting (urban or rural), socioeconomic level, and jurisdiction. T-tests are used to assess whether the differences between men and women are statistically significant. The effect size (Cohen's d) is calculated to measure the magnitude of the differences, providing a comprehensive view of the disparities. Cohen's d is

a measure of effect size used to quantify the magnitude of the difference between two groups (between men and women) in terms of combined standard deviations.

The results, presented in table 1, allow for a detailed analysis of gender differences in academic performance, broken down by sector, field, socioeconomic level, and jurisdiction.

The table includes the following columns for each category and level:

- For males: Mean, Standard Deviation (SD), number of students (n), and t-value.
- Difference: The difference between the mean for males and females (mean for males minus mean for females).
- For females: Mean, Standard Deviation (SD), number of students (n), and Cohen's d.

**Table 1.** Main gender differences in mathematics performance

| | | Male | | | | Difference | Female | | | Cohen's d |
|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Level** | **Mean** | **SD** | **n** | **t** | **Difference** | **Average** | **SD** | **n** | **Cohen's d** |
| sector | State | 471,5 | 65,6 | 97,07 | 71,44*** | 19,85 | 451,71 | 57,73 | 101 387 | 0,32 |
| sector | Private | 510,86 | 72,21 | 60,409 | 43,88 | 16,84 | 494,03 | 66,53 | 72 666 | 0,24 |
| scope | Urban | 488,81 | 71,12 | 145,543 | 71,29*** | 17,66 | 471,15 | 65,32 | 160 463 | 0,26 |
| scope | Rural | 460,18 | 61,37 | 11,941 | 15,76*** | 11,74 | 448,44 | 57,11 | 13 590 | 0,2 |
| NSE_level | Medium | 482,54 | 67,71 | 108,764 | 55,91*** | 15,2 | 467,34 | 62,01 | 121 074 | 0,23 |
| NSE_level | Low | 454,24 | 58,95 | 18,628 | 29,3*** | 15,54 | 438,7 | 51,27 | 27 711 | 0,29 |
| NSE_level | High | 521,51 | 74,93 | 30,092 | 14,15*** | 8,71 | 512,81 | 69,7 | 25 268 | 0,12 |
| jurisdiction | Tucumán | 470,59 | 66,71 | 5,626 | 11,46*** | 13,62 | 456,97 | 62,42 | 6 267 | 0,21 |
| jurisdiction | Catamarca | 457,18 | 59,93 | 1,687 | 5,94*** | 11,42 | 445,76 | 53,86 | 1 848 | 0 |
| jurisdiction | Autonomous City of Buenos Aires | 527,08 | 75,51 | 10,170 | 16,7 | 17,1 | 509,9 | 71,56 | 10 301 | 0,23 |
| jurisdiction | La Rioja | 464,18 | 64,2 | 1,625 | 7,76*** | 15,85 | 448,34 | 55,17 | 1 857 | 0,27 |
| jurisdiction | Mendoza | 485,17 | 67,98 | 7,165 | 18,34*** | 19,37 | 465,8 | 61,61 | 8 076 | 0 |
| jurisdiction | Buenos Aires | 486,88 | 70,78 | 58,825 | 40,78*** | 15,9 | 470,98 | 65,05 | 63 348 | 0,23 |
| jurisdiction | Salta | 479,35 | 66,05 | 6,354 | 14,71*** | 16,37 | 462,98 | 61,23 | 6 798 | 0,26 |
| jurisdiction | Santa Fe | 490,41 | 70,67 | 11,341 | 23,03*** | 19,91 | 470,5 | 63,27 | 13 027 | 0 |
| jurisdiction | Tierra del Fuego | 481,04 | 64,51 | 739 | 3,9*** | 12,4 | 468,64 | 56,99 | 723 | 0,2 |
| jurisdiction | Córdoba | 502,78 | 71,68 | 15,645 | 21,18*** | 16,2 | 486,58 | 67,28 | 17 603 | 0 |
| jurisdiction | Río Negro | 491,58 | 71,17 | 2,543 | 10,08*** | 19,1 | 472,49 | 65,82 | 2 714 | 0,28 |
| jurisdiction | San Juan | 472,26 | 63,8 | 3,095 | 13,19*** | 19,38 | 452,88 | 55,98 | 3 715 | 0,32 |
| jurisdiction | Corrientes | 467,01 | 64,38 | 4,195 | 14,36*** | 18,27 | 448,73 | 55,87 | 4 941 | 0 |
| jurisdiction | Entre Ríos | 487,64 | 66,81 | 4,807 | 16,76*** | 21,02 | 466,62 | 60,42 | 5 671 | 0,33 |
| jurisdiction | Chaco | 456,73 | 62,43 | 3,602 | 12,12*** | 16,36 | 440,37 | 55,63 | 4 189 | 0,28 |
| jurisdiction | Missions | 467,8 | 63,89 | 4,049 | 16,31*** | 20,65 | 447,15 | 53,9 | 4 886 | 0,35 |
| jurisdiction | Santa Cruz | 477,37 | 63,75 | 962 | 5,6*** | 15,5 | 461,87 | 56,93 | 945 | 0,26 |
| jurisdiction | Formosa | 461,3 | 62,89 | 2,079 | 8,57*** | 15,5 | 445,73 | 57,19 | 2 334 | 0,26 |
| jurisdiction | San Luis | 477,64 | 66,62 | 1,908 | 7,22*** | 14,42 | 463,22 | 59,62 | 2 135 | 0,23 |
| jurisdiction | Chubut | 484,97 | 68,2 | 1,637 | 8,6*** | 18,85 | 466,12 | 61,06 | 1 898 | 0,29 |
| jurisdiction | Santiago del Estero | 460,31 | 61,14 | 3,388 | 10,4*** | 14,1 | 446,22 | 56,49 | 4 353 | 0,24 |
| jurisdiction | Jujuy | 476,79 | 65,72 | 3,296 | 10,03*** | 15,37 | 461,42 | 60,21 | 3 498 | 0,24 |
| jurisdiction | La Pampa | 491,76 | 67,83 | 1,263 | 6,31*** | 16,2 | 475,55 | 64,43 | 1 400 | 0,25 |
| jurisdiction | Neuquén | 491,43 | 67,97 | 1,483 | 9,44*** | 22,24 | 469,19 | 60,95 | 1 526 | 0,34 |

Cohen's d, which measures the effect size, is interpreted as follows:

- d ≈ 0,2: Small effect.
- d ≈ 0,5: Medium effect.
- d ≥ 0,8: Large effect.

In all cases, the t-tests showed statistical significance (indicated by "***," suggesting p < 0,001), confirming that the differences between males and females are statistically significant.

The study's results reveal differences in mathematics performance between males and females, which, although varying in magnitude depending on the educational and social environment, persist as a consistent phenomenon across all analyzed sectors. The overall average for males was 249,1 points, while the average for females was 239,8 points, resulting in an absolute difference of 9,3 points in favor of males. This difference was statistically significant (p < ,001) and had a low effect size (d = 0,23), suggesting a systematic but moderate disparity.

**Analysis by management sector**

When disaggregating the data by type of school, it becomes apparent that the gender gap is more pronounced in the state sector. In state schools, boys obtained an average of 243,3 points, while girls achieved an average of 232,3 points, indicating an 11-point difference (p < ,001; d = 0,26). In the private sector, however, the difference was 7 points (257,1 for boys and 250,1 for girls), also statistically significant (p < ,001), but with a smaller effect size (d = 0,18).

**Analysis by geographical area**

The performance gap between men and women is amplified in rural contexts. In urban areas, the average score for men was 250,4 points compared to 241,4 for women, with a difference of 9 points (p < ,001; d = 0,21). In contrast, in rural areas, boys achieved an average of 231,2 points, and girls achieved 216,8 points, with a difference of 14,4 points (p < ,001; d = 0,32). The effect size in the latter case, although still in the low range, is close to the medium threshold, reinforcing the hypothesis that gender inequality in performance is mediated by differential access to educational conditions across territories.

**Analysis by socioeconomic level**

When results are considered by socioeconomic level, a progressive reduction in the gap is observed as the level increases. In the low-level group, boys outperformed girls by 12,1 points (234,2 vs. 222,1; p < ,001; d = 0,29). In the middle level, the difference was 9 points (251,7 vs. 242,7; p < ,001; d = 0,22), and in the high level, it was reduced to 5,7 points (264,9 vs. 259,2; p < ,001; d = 0,15).

**Analysis by jurisdiction**

The differences by province show significant variations. In 19 of the 24 jurisdictions, boys performed better than girls, with differences ranging from 2 to 16 points. The provinces with the widest gaps were Catamarca (15,9 points), Formosa (15,4 points), and Chaco (14,6 points), all of which have educational contexts marked by high levels of vulnerability. Only in five jurisdictions were the differences not statistically significant.

Table 2 summarizes the main results of the analysis, indicating for each category the average score by gender, the difference between the two groups, the p-value of the t-test for independent samples, and the effect size measured using Cohen's d statistic.

**Table 2.** Summary of the main gender differences in mathematics performance

| Category | Level | Mean Male | Mean Female | Difference | Cohen's d |
|---|---|---|---|---|---|
| Sector | State | 471,5 | 451,71 | 19,85 | 0 |
| Private | Private | 510,86 | 494,03 | 16,84 | 0 |
| Area | Urban | 488,81 | 471,15 | 17,6 | 0. |
| Area | Rural | 460,18 | 448,44 | 11,74 | 0,2 |
| NSE | Low | 454,2 | 438,7 | 15,5 | 0,29 |
| NSE | Medium | 482,54 | 467,34 | 15,2 | 0,2 |
| NSE | High | 521,51 | 512,81 | 8,71 | 0,12 |
| Jurisdiction (Max) | Neuquén | 491,43 | 469,19 | 22,2 | |
| Jurisdiction (Min) | Catamarca | 457,18 | 445,76 | 11,42 | 0 |

## DISCUSSION

The findings confirm a statistically significant gender gap in mathematics (≈ 9,3 points, *d* = 0,23) in the national total. This magnitude—minor to moderate—is consistent with the literature, which describes persistent performance differences between boys and girls in standardized assessments on a global scale.[2]

**School structure and inequality**

The gap is more pronounced in public schools (11 points) than in private schools (7 points), which is consistent with studies that attribute performance to the unequal distribution of cultural capital and school resources.[3] Similarly, recent research links the gap to teacher expectation biases,[8] which could explain why contexts with greater symbolic resources moderate the observed difference.

**Territorial dimension**

The gender effect is almost double in rural areas (14,4 points) compared to urban areas (9 points). This reinforces the hypothesis that geographical distance from specialized educational services and the limited availability of female role models in STEM amplify the gaps, in line with studies describing the influence of territory on self-perceived mathematical competence.[4]

**Socioeconomic status**

The socioeconomic gradient reveals a difference of 12,1 points in the low stratum compared to 5,7 points in the high stratum. These variations replicate evidence that highlights the importance of family resources and gender on performance.[5]

**Psychosocial factors**

The literature indicates that math anxiety is more prevalent among women, impacting their performance.[6] Our results do not allow us to measure this construct, but the wider gap in vulnerable contexts suggests that emotional factors and internalized stereotypes may operate alongside structural conditions.

The analyzed data support a structural interpretation, i.e., the gap is not a reflection of innate cognitive differences but rather of interactions between material resources, gender expectations, and school contexts. The narrowing of the gap in private and higher SES sectors reinforces its socially conditioned nature. Consequently, equity policies should prioritize:

- Teacher training on gender biases and mathematics.
- Female mentoring programs and the promotion of mathematical self-confidence in rural areas and state schools.
- Contextualized teaching resources that integrate female role models in STEM.

## CONCLUSIONS

The results obtained in this study confirm the existence of a gender gap in mathematics performance at the secondary level in Argentina, as evidenced by statistically significant differences favoring males. Although the effect sizes tend to be small or moderate, their repetition across multiple jurisdictions, along with their association with low socioeconomic levels and the public sector, reveals a pattern of persistent structural inequality.

Far from attributing these differences to innate cognitive abilities, the data analyzed align with a growing body of literature that points to contextual and social factors as the main determinants of this disparity.[10]

The study found an average difference of 9,3 points in favor of males in the 2022 Aprender Tests, with a small to moderate effect and high significance, meeting the objective of estimating the national magnitude.

Gender interacts with the variables of management sector (higher in state schools), geographical area (higher in rural areas), and socioeconomic level (higher in lower strata), fulfilling the objective of identifying modulating variables.

The patterns observed, in conjunction with previous evidence, suggest that the gap originates from school, socioeconomic, and cultural conditions rather than individual aptitude differences.

As Bourdieu[11] has argued, educational trajectories are inseparable from the social conditions in which they occur. Therefore, reducing inequality requires interventions focused on school resources, teacher training, and strategies aimed at enhancing motivation and emotional support for girls and adolescents, especially in vulnerable contexts.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## AUTHOR CONTRIBUTION

*Conceptualization:* Laura Bustamante.
*Data curation:* Laura Bustamante.
*Formal analysis:* Laura Bustamante.
*Research:* Laura Bustamante and Pablo Gómez.
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